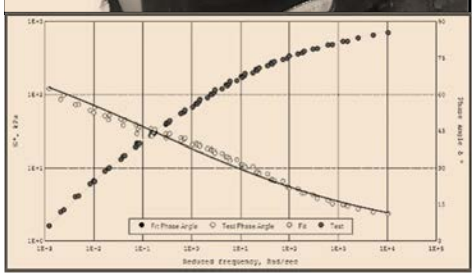

A Simple Method for Assessing An Asphalt Binder Quality Obtained from Different Sources in BMD

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Introduction

Background:

DOTs are integrating sustainable materials into asphalt mixtures to achieve cost-effective and eco-friendly pavements.

Challenges:

1. These sustainable materials must maintain pavement performance. Since traditional volumetric designs don't consider new materials, DOTs are moving to the Balanced Mix Design (BMD) method, which includes performance testing.

2. A major challenge is ensuring binder consistency, as changes in source or formulation can unbalance the mix.

Goal:

Identify rheological parameters to assess binder quality and develop a rapid test method.

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Rheological Parameters

- Point Parameters: Focus on binder hardness (e.g., G-R parameter).
- Shape Parameters: Describe viscoelastic behavior (e.g., phase angle, master curve).
- Key Focus: Glover-Rowe (G-R) parameter and phase angle at 10 MPa (δ_{10MPa}).

Objectives

1. Evaluate point and shape rheological parameters of asphalt binders.
2. Identify effective parameters for distinguishing binder quality.
3. Validate selected parameters with the IDEAL-CT test.
4. Develop a rapid testing method for use in production.

Superpave Binder Specifications – Fatigue Cracking Parameter G*sinδ

- The Superpave asphalt binder specification uses the parameter **G*sinδ** to grade asphalt binders according to cracking resistance at intermediate pavement temperatures.
- Temperatures listed in the specification range from 4 to 40 °C.
- **G*sinδ** is measured using a dynamic shear rheometer (DSR).

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Materials Overview

- Seventeen (17) asphalt binders sourced from various suppliers.
- Inclusion of three poor-quality binders for benchmarking.
- Types: Unmodified, polymer-modified, and asphalt rubber.

Experimental Plan

- Materials: 20 asphalt binders from four different sources, including high and low-quality samples.
- Testing: DSR and BBR tests, master curve construction, and IDEAL-CT validation.
- Analysis: Ranking of binders based on parameters to correlate with CT_{Index}.

Experimental Plan

- Superpave Mix Design: Designed using seven binders to validate parameters.

- Testing Conditions: Binders tested in unaged, RTFO, and PAV-aged conditions.

NESMEA 2024 ✦ Springfield, MA

Asphalt Binders

	Source A	Source B	Source C	Source D	Source E (Poor Quality)	Lab Formulated (Poor Quality)
PG52-34 (Base Binder)		×		×		
PG58-28 (Base Binder)	×		×	×		
PG64-28 (Base Binder)		×				
PG64-16					×	
PG64-22						×
PG64S-28	×	×	×	×		×
PG64E-28	×	×		×		
PG64E-34	×					
PG76E-34		×				
Asphalt Rubber	×			×		

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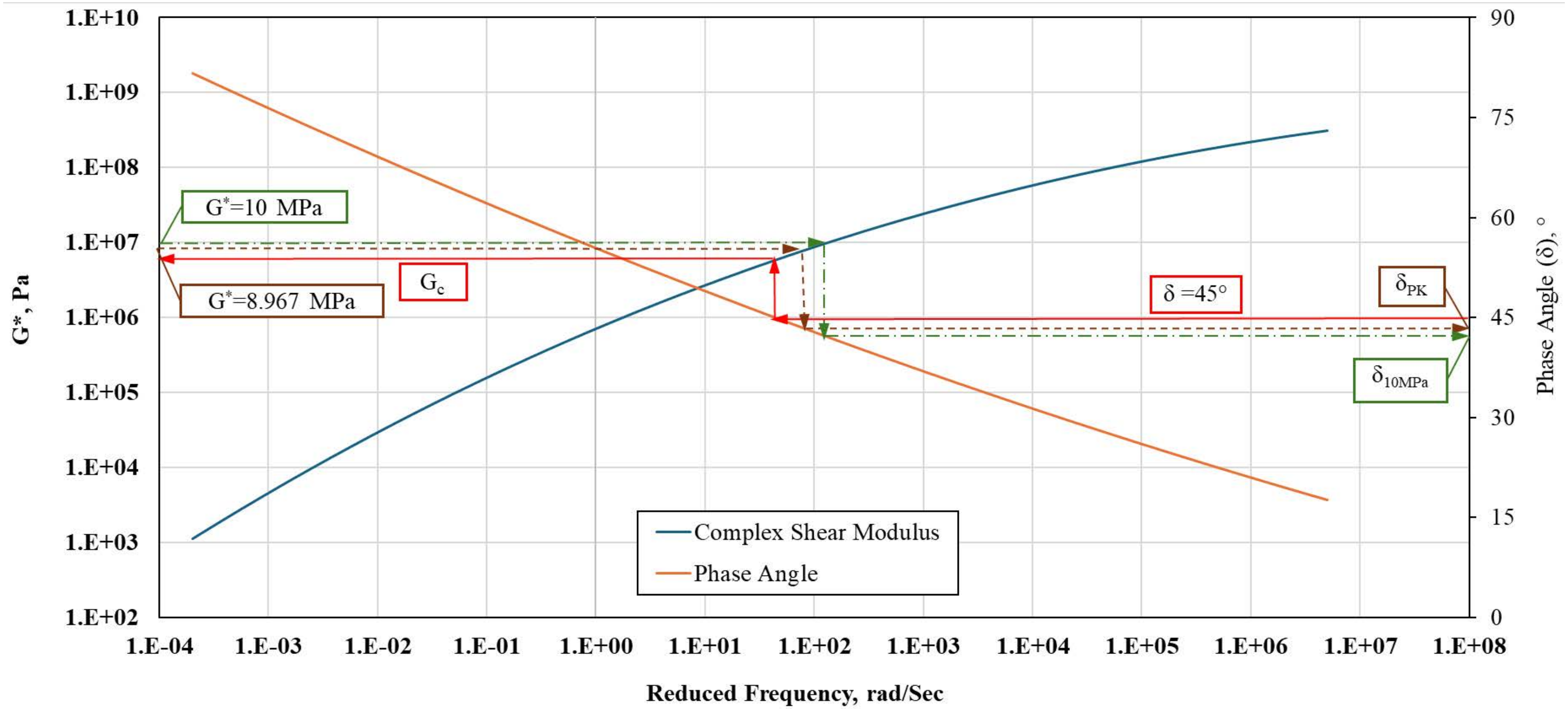
Master Curve Insights

- Master Curve: Relationship between stiffness and frequency.
- Time-temperature superposition principle applied for data shifts.
- Provides a holistic view of binder behavior across temperatures.



G*=10 MPa
G*=8.967 MPa
G_c
δ =45°
δ_PK
δ_10MPa
Complex Shear Modulus
Phase Angle
G*, Pa
Phase Angle (δ), °
Reduced Frequency, rad/Sec
1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
90
75
60
45
30
15
0
1.E-04
1.E-03
1.E-02
1.E-01
1.E+00
1.E+01
1.E+02
1.E+03
1.E+04
1.E+05
1.E+06
1.E+07
1.E+08

Point & Shape Rheological Parameters

Point

- These can be considered to capture the **hardness** of asphalt binders. They include specific values on the master curve, such as the G*, ω_c and the G-R parameter at a reference temperature and frequency.

Shape

- They describe the overall shape/form of the master curve, reflecting the **asphalt binder's response** over a wide range of conditions. In industry, currently four parameters are being considered as additional specification parameters that effectively describe the shape of the master curve: (1) R-value, (2) log G_c, (3) δ_{PK} or δ_{10MPa} and (4) $\Delta T_{c.}$

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Point Parameters

- Point Parameters assess specific binder characteristics at defined conditions.
- Focuses on binder hardness and stiffness at a particular temperature or frequency.
- Examples: Glover-Rowe (G-R) parameter, crossover frequency (ω_c), etc.

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Glover-Rowe (G-R) Parameter

- G-R parameter is calculated at 15°C and 10 rad/s using the formula: $G^*(\cos\delta)^2/\sin\delta$.
- Provides insights into cracking potential of binders under intermediate temperatures.
- Higher G-R values indicate increased susceptibility to cracking.

Significance of G-R Parameter

- Effective in differentiating between high and low-quality binders.
- Particularly useful in environments with frequent intermediate-temperature cycling.
- Allows DOTs to identify binders that may lead to early cracking failures.

Crossover Frequency (ω_c)

- Defines the frequency where the binder transitions from elastic to viscous behavior.
- Lower ω_c indicates a stiffer, more elastic binder; higher ω_c suggests softer binder.
- Significant for understanding how binders respond under dynamic loading conditions.

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Shape Parameters

- Shape parameters describe the overall behavior of the binder over a range of conditions.

- Focuses on viscoelastic behavior and how it changes with temperature and frequency.

- Examples: Phase angle at 10 MPa (δ_{10MPa}), Rheological Index (R-value), etc.

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Phase Angle at 10 MPa (δ_{10MPa})

- δ_{10MPa} represents the phase angle when the binder's complex modulus (G*) is 10 MPa.
- Provides a benchmark for viscoelastic behavior at a defined stiffness level.
- Important for assessing a binder's ability to resist cracking at intermediate temperatures.

Interpretation of δ_{10MPa}

- Lower δ_{10MPa} values suggest a more elastic binder, better for stress relaxation.
- Higher δ_{10MPa} values indicate a more viscous binder, potentially less effective in resisting cracking.
- Useful for comparing performance across different binders with similar grades.

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Rheological Index (R-value)

- R-value measures the rate of change in stiffness across temperatures.
- Reflects the curvature of the master curve, indicating binder's aging behavior.
- Higher R-values suggest flatter curves, beneficial for high-temperature performance but may reduce intermediate-temperature flexibility.

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Comparing Point and Shape Parameters

- Point parameters provide specific measurements, ideal for rapid quality checks.
- Shape parameters offer a comprehensive view, capturing overall behavior changes.
- Together, they ensure a balanced understanding of binder quality and performance.

Master Curve Analysis

- Master Curve: Illustrates the relationship between binder stiffness and frequency.
- Derived from DSR data at multiple temperatures.
- Essential for understanding binder performance across diverse conditions.

Point Parameters Analysis

- G-R Parameter: Evaluated at 15°C and 10 rad/s.
- Distinguishes between high and low-quality binders.
- Provides insights into binder stiffness and potential for cracking.

Shape Parameters Analysis

- δ_{10MPa}: Phase angle at a specific modulus of 10 MPa.
- Effective in differentiating binder performance at intermediate temperatures.
- Correlates well with mixture cracking resistance.

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Numerical Rankings of Point and Shape Parameters

(1 = Best & 20 = Worst)

	Point Parameter G-R at 15°C and 10 rad/s		**Shape Parameter** Phase angle at 10 MPa (δ_{10MPa})		**Shape Parameter** Log cross-over modulus (log G_c)	
	RTFO	**20 Hour PAV**	**RTFO**	**20 Hour PAV**	**RTFO**	**20 Hour PAV**
PG52-34	2	4	2	4	2	4
PG76-34	4	3	8	7	8	7
PG64-28 Base	7	19	7	10	7	9
PG64E-28	17	11	16	12	16	13
PG64-16	20	20	3	2	4	2
PG64-22 Lab Formulated	10	17	20	20	20	20
PG64-28 Lab Formulated	11	13	17	19	17	19

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Superpave Mix Design

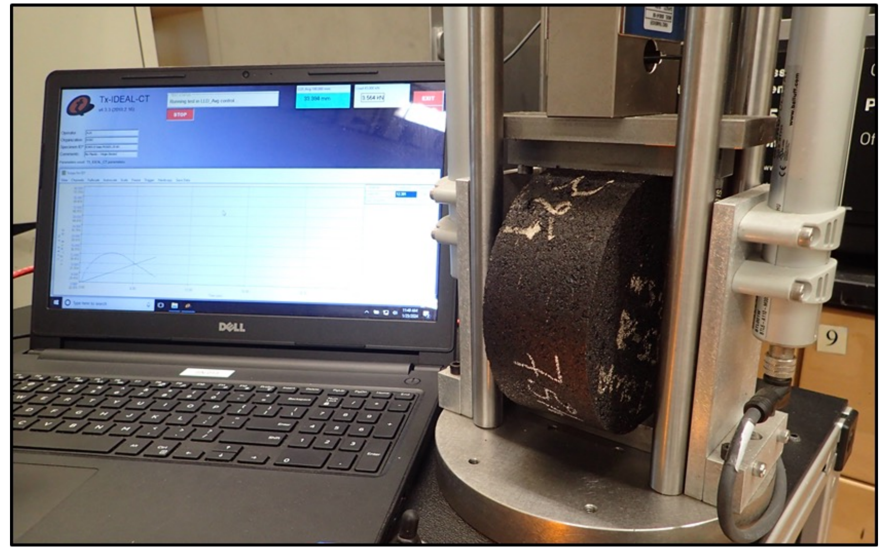
- 12.5 mm dense-graded asphalt mixture.
- Used <u>seven</u> selected binders to validate parameters.

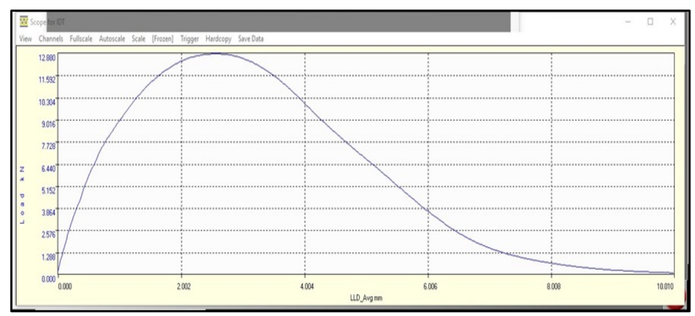
IDEAL-CT Test Overview

- ASTM D8225-19 method used for intermediate temperature cracking assessment.

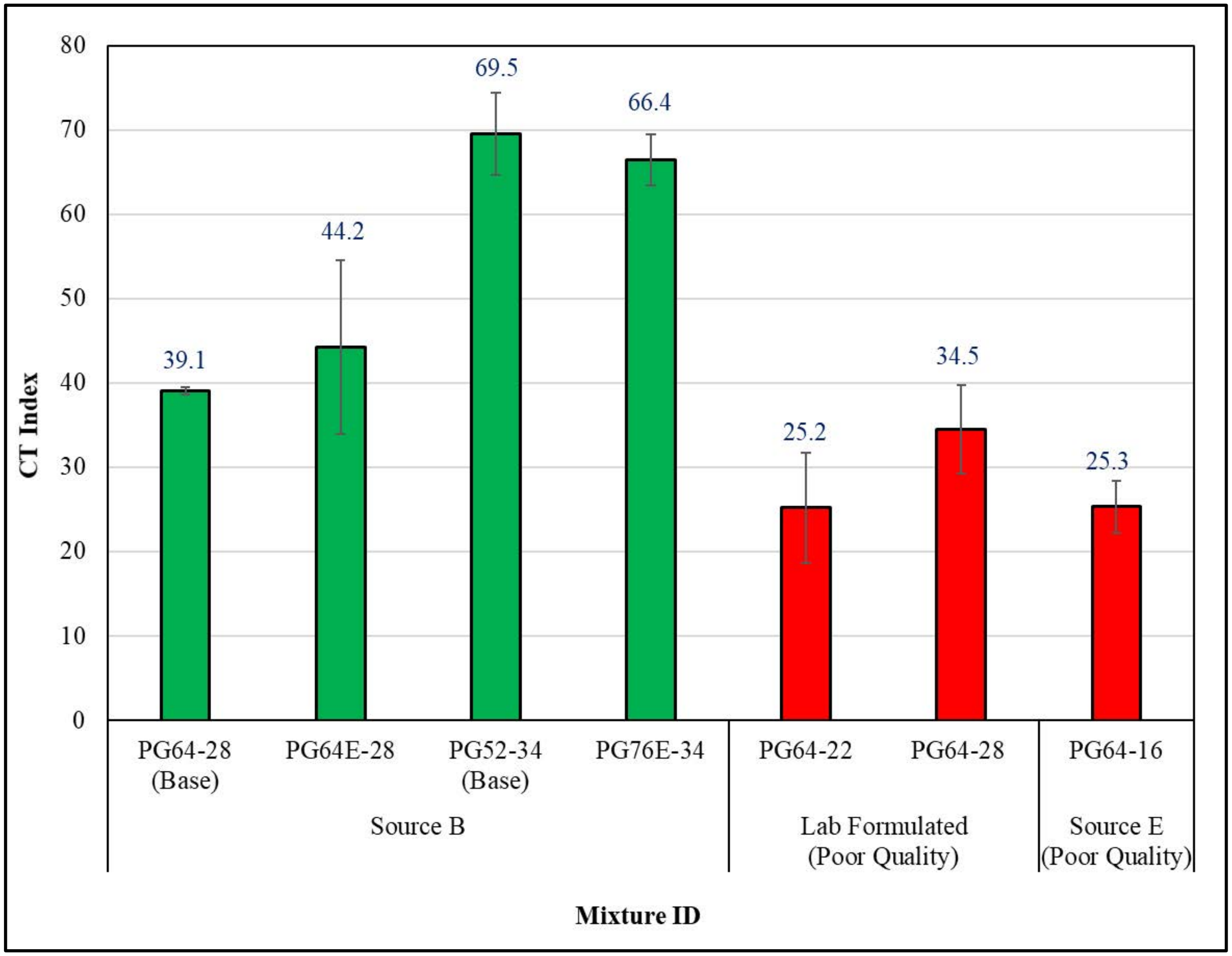
- CT_{Index}: Higher values indicate better cracking resistance.

- Validation of selected binder parameters through mixture testing.





IDEAL-CT Results



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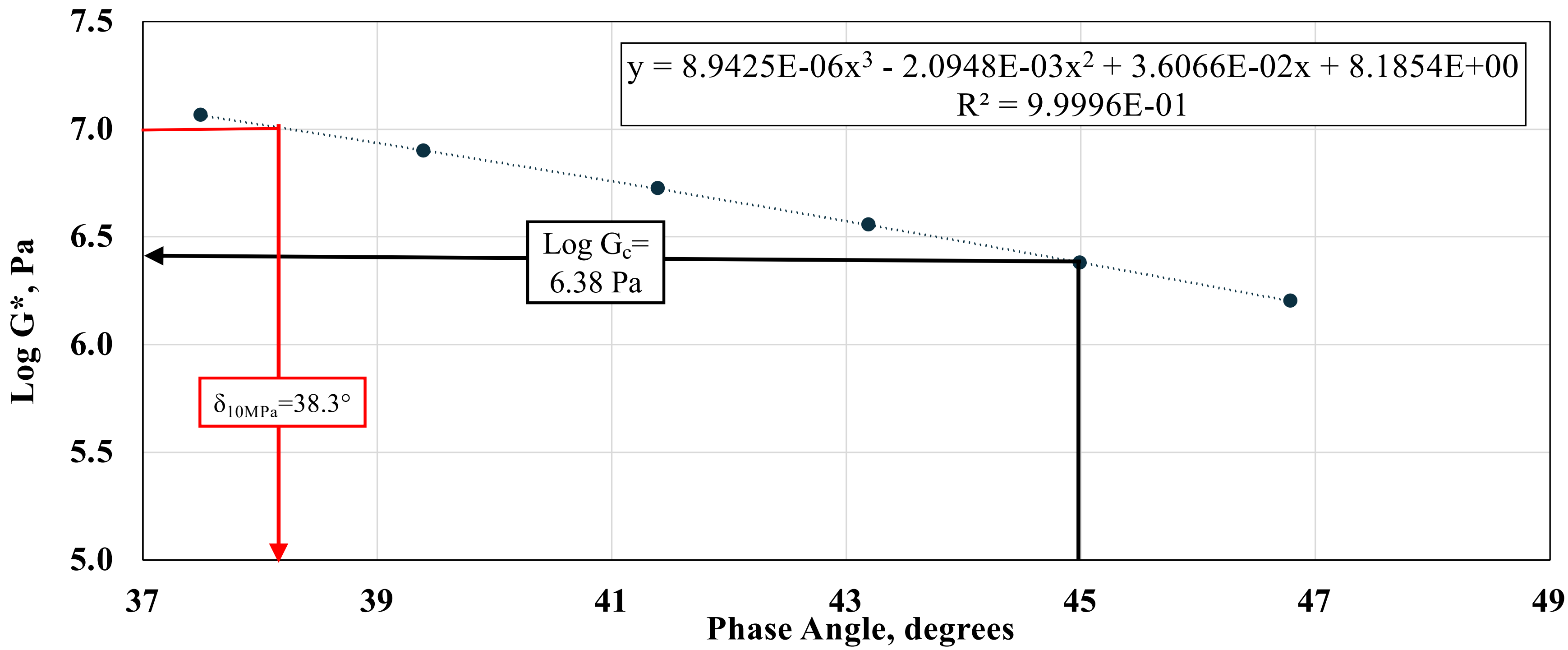
IDEAL-CT Results

- Mixtures with poor-quality binders showed lower CT_{Index} values.
- Correlation with G-R and δ_{10MPa} rankings verified.
- Supports use of these parameters for quality control.

Rapid Testing Method Development

- Goal: Simplified DSR method for G-R and δ_{10MPa}.
- Reduces testing time while maintaining accuracy.
- Focus on practical application in production environments.

Rapid Testing Method Development



Comparison of Testing Approaches

- Traditional Master Curve vs. Simplified Method.
- Advantages of time savings and ease of use.
- No significant loss in data quality or predictive power.

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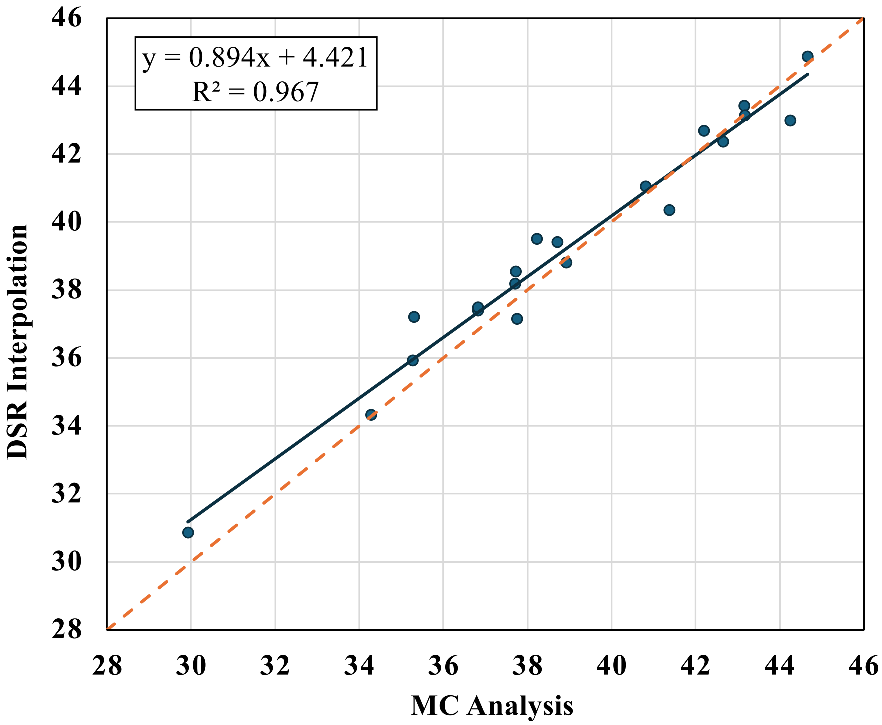
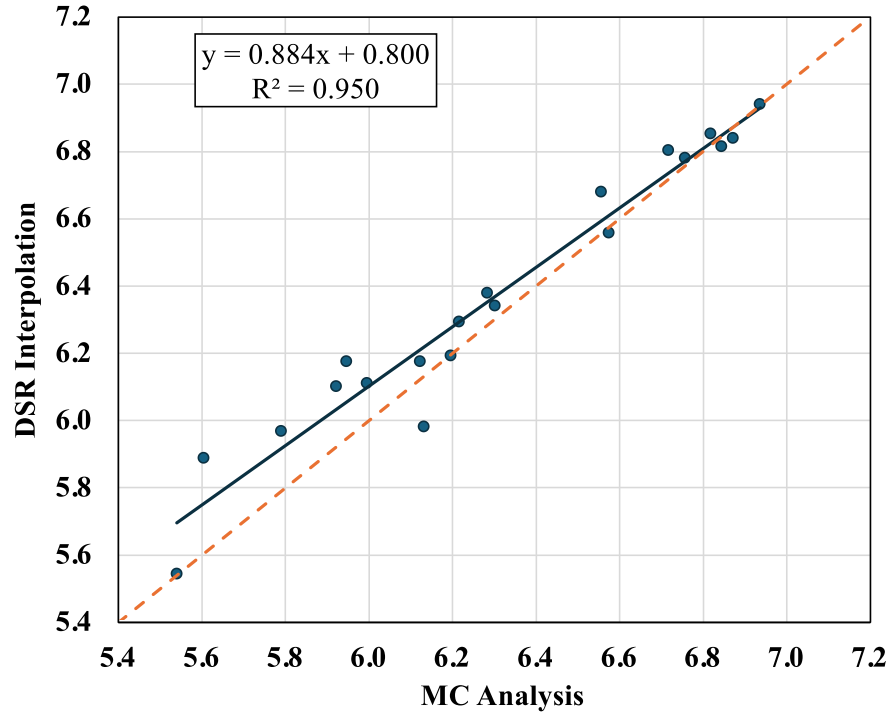
Validation of Simplified Approach

- Strong agreement between simplified and traditional methods.
- Ensures practical applicability without compromising data integrity.
- Enables faster decision-making during production.

Validation of Simplified Approach





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Practical Implications for Industry

- Potential for integration into DOT specifications.
- Streamlines quality control processes for contractors.
- Supports sustainable practices by ensuring material performance.

Recommendations for Implementation

- Incorporate G-R and δ_{10MPa} into BMD specifications.
- Use simplified method for routine binder evaluations.
- Focus on training for testing personnel to ensure consistency.

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Conclusions

1. G-R and δ_{10MPa} are effective for assessing binder quality.
2. Simplified testing method ensures consistency and efficiency.

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Thank you

Questions?